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Performance Evaluation of Round Robin and Proportional Fair Scheduling Algorithms for Constant Bit Rate Traffic in LTE

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***Abstract*— Scheduling is a key Radio Resource Management (RRM) mechanism for realizing Quality of Service (QoS) requirements and optimizing system performance of Long Term Evolution (LTE) network. Scheduling is the process of dynamically allocating physical resources to User Equipments (UEs) based on scheduling algorithms implemented at the LTE base station. Various algorithms have been proposed by network designers/researchers as the implementation of scheduling algorithm is an open issue in LTE standard. The choice of scheduling algorithm critically impacts resource utilization and the overall performance of LTE network. This paper makes an attempt to study and compare the performance of Round Robin (RR) and Proportional Fair (PF) scheduling algorithms for Constant Bit Rate (CBR) traffic scenario. Performance metrics considered for simulation studies are throughput, delay and jitter.**

Keywords-LTE; QoS; Scheduling; Round Robin; Proportional Fair

I. INTRODUCTION

Long Term Evolution (LTE) is a broadband wireless access network offering a rich suite of multimedia applications such as 3D videoconferencing [1], mobile HD TV and real time streaming videos at very high vehicular speeds. These applications have heterogeneous Quality of Service (QoS) requirements such as priority, transmission delay, jitter, packet loss rate, packet error rate etc., to provide better user experience. QoS provisioning offers a challenge for the LTE network designers to efficiently utilize the limited available radio resources in a highly fading wireless medium. In order to meet this challenge, LTE standard incorporates Radio Resource Management (RRM) mechanisms such as Call Admission Control (CAC), scheduling etc., which are open issues for designers. Scheduling is a crucial RRM mechanism which divides and allocates radio resources among different users while maintaining QoS to optimize system performance.

The scheduling in both downlink and uplink is carried out by scheduler present at the Medium Access Control (MAC) sublayer of eNodeB (eNB). Since scheduling algorithm for eNB MAC scheduler is not standardized, LTE network designers have proposed scheduling algorithms which results in significantly different levels of user and system performance. Hence in this paper an attempt has been made to evaluate the performance of Round Robin (RR) and Proportional Fair (PF) scheduling algorithms for Constant Bit Rate (CBR) traffic scenario using QualNet network simulator.

The rest of the paper is organized as follows. Section II gives a brief insight of LTE system overview and Section III describes QoS and Evolved Packet System (EPS) Bearers. RR and PF scheduling algorithms in LTE are described in Section IV. Simulation studies and results are given in section V and Section VI concludes the paper.

II. LTE SYSTEM OVERVIEW

LTE, developed by Third Generation Partnership Project (3GPP), is designed to support ubiquitous delivery of multimedia services with IP-based network architecture and Orthogonal Frequency Division Multiple Access (OFDMA) based air-interface technology. The air-interface related attributes of the LTE Rel-8 are summarized in Table I.

TABLE I. LTE PERFORMANCE SPECIFICATIONS

Metric	Specifications
Spectral Flexibility	1.4, 3, 5, 10, 15 and 20 MHz
Peak data rate	• Downlink (2 Channel MIMO): 100 Mbps • Uplink (Single Channel Tx): 50 Mbps (20 MHz channel)
Supported antenna Configurations.	• Downlink: 4x2, 2x2, 1x2, 1x1 • Uplink: 1x2, 1x1
Latency	• Control plane: Less than 100 ms to establish User plane • User plane: Less than 10 ms from User Equipment (UE) to server
Mobility	• Optimized for low speeds (0-15 km/hr) • High performance at speeds up to 120 km/hr • Maintain link at speeds up to 350 km/hr
Coverage	• Full performance up to 5 km • Slight degradation in 5 km – 30 km
Spectrum efficiency	• Downlink: 3 to 4 times HSDPA Rel. 5 • Uplink : 2 to 3 times HSUPA Rel. 6

The architecture of LTE is termed as EPS which consists of Evolved Packet Core (EPC) and Evolved-Universal Terrestrial Radio Access Network (E-UTRAN) as shown in Fig. 1[2, 3].

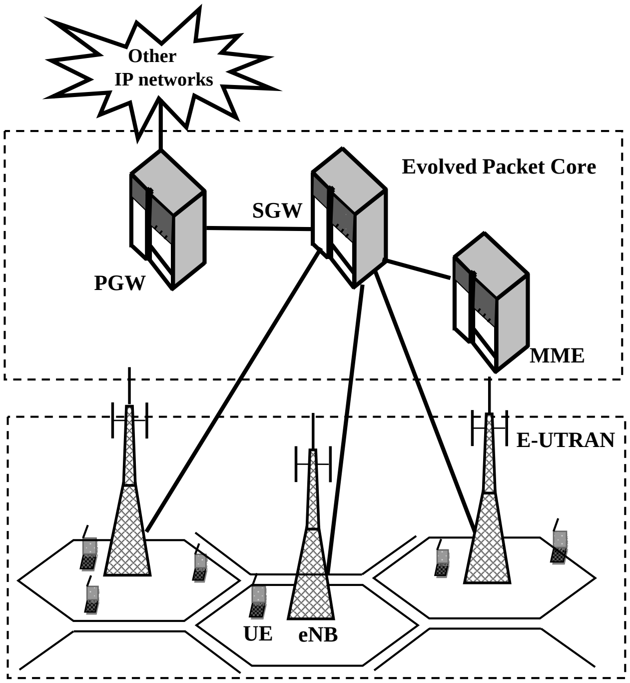


Figure 1. Simplified LTE architecture

EPC is an IP-based core network responsible for providing access to both 3GPP and non-3GPP technologies. The functionality of EPC includes mobility management, charging, authentication and setup of end-to-end connections. In order to accomplish these functionalities, EPC consists of logical nodes such as Mobility Management Entity (MME), Serving Gate Way (SGW) and Packet data network Gate Way (PGW).

The E-UTRAN is responsible for the RRM mechanisms such as scheduling, CAC, retransmission protocols, coding, power control, handover and various multi-antenna schemes [4]. It contains single type of network element called eNB, which act as the terminal point for all radio communications carried out by the User Equipment (UE). Also, eNB relays data flows between the radio connection and the EPC network.

III. Quality of Service and EPS Bearers

QoS is the concept of providing a particular quality guarantee for a specific type of service. Since LTE is an all IP network, QoS provisioning becomes one of the greatest challenges for providing a range of IP-based services like VoIP, FTP etc. In order to provide QoS, LTE has defined EPS bearer which uniquely identifies a packet flow that would receive common QoS treatment between the UE and the gateway [5, 6]. Multiple bearers can be established for a user in order to provide different QoS streams or connectivity to different packet data networks.

Bearers can be classified into two categories: Guaranteed Bit Rate (GBR) bearers and Non-GBR bearers based on the nature of the QoS requirements to support multiple applications in UE at any time.

GBR: For GBR bearers, dedicated transmission resources are permanently allocated at bearer establishment or modification. Bit rate higher than the GBR called Maximum Bit Rate (MBR) may be allowed for a GBR bearer if resources are available.

Non-GBR: For non-GBR bearers, no bandwidth resources are allocated permanently, hence they do not guarantee any particular bit rate.

The EPS QoS concept is class-based, wherein each bearer is assigned a scalar QoS Class Identifier (QCI). The QCI specifies the packet forward treatment associated with bearer. The standardized QCI characteristics for the bearer traffic between UE and the gateway are specified in terms of bearer type (GBR or non-GBR), priority, packet delay budget, and packet error loss rate [7]. Standardized QCIs for LTE are given in Table II.

TABLE II. STANDARDIZED QCIS FOR LTE

QCI	Bearer Type	Priority	Packet Delay Budget (ms)	Packet Error Loss Rate	Example Services
1	GBR	2	100	10^{-2}	Conversational voice
2	GBR	4	150	10^{-3}	Conversational video (live streaming)
3	GBR	5	300	10^{-6}	Non-conversational video (buffered streaming)
4	GBR	3	50	10^{-3}	Real-time gaming
5	Non-GBR	1	100	10^{-6}	IMS signaling
6	Non-GBR	7	100	10^{-3}	Voice, video (live streaming), interactive gaming
7	Non-GBR	6	300	10^{-6}	Video (buffered streaming)
8	Non-GBR	8	300	10^{-6}	TCP-based (e-mail), chat, FTP, p2p file sharing, progressive video etc.
9	Non-GBR	9	300	10^{-6}	

IV. Round Robin (RR) and Proportional Fair (PF) Scheduling Algorithms in LTE

Scheduling algorithm is employed to select different users in time domain and different Physical Resource Blocks (PRBs) in frequency domain depending on the channel conditions and bandwidth requirements of the user while ensuring fairness, stability and throughput optimality [8]. Several scheduling algorithms have been designed for efficient scheduling based on the following three properties: low complexity, bounded delay and fairness to optimize system performance [9]. In this section, RR and PF scheduling algorithms are described.

A. Round Robin (RR):

RR scheduling algorithm maintains a constant delay between two transmissions to the same user. This is an advantage for modern voice and video communications which have strict delay requirements. RR scheduling algorithm also has the advantage of reduced overhead, since the eNB does not need to sacrifice transmission time to inform the users in every block about their allocated slot positions [10].

B. Proportional Fair (PF):

The PF scheduling algorithm provides a good tradeoff between system throughput and fairness by selecting the user with highest instantaneous data rate relative to its average data rate. However, in every block PF scheduler informs the UEs about their allotted slot positions of radio resources thus increasing scheduler complexity and overhead.

V. SIMULATION STUDIES AND RESULTS

The performances of RR and PF scheduling algorithms for CBR traffic are evaluated using QualNet 5.2 simulator by considering an eNB and ten pairs of UEs in a single cell environment. Two ray path loss model with lognormal shadowing is considered for the simulation studies. The remaining simulation parameters are listed in Table III.

TABLE III. SIMULATION PARAMETERS

Property		Value
Simulation-Time		20S
Simulation-Area		5Km X 5Km
Propagation-Channel-Frequency		2.4GHz
Propagation-Model		Statistical
Shadowing mean		4dB
Channel-Bandwidth		10MHz
Propagation-Speed		$3x10^8$ mps
Antenna-Model		Omni directional
eNB parameters	MAC-LTE-Scheduler-Type	Round-Robin
		Proportional-Fairness
	PHY-LTE-Tx-Power	46dBm
	PHY-LTE-Num-Rx-Antennas	2
	Antenna-Height	15m
	Antenna-Gain	14dB
	MAC-LTE-Transmission-Mode	1(SIMO)
UE parameters	MAC-LTE-Scheduler-Type	Simple-Scheduler
	PHY-LTE-Tx-Power	23dBm
	PHY-LTE-Num-Rx-Antennas	1
	Antenna-Height	1.5m
	Antenna-Gain	0.0dB

The snapshot of the scenario designed for simulation study using QualNet 5.2 simulator is shown in Fig. 2.Following subsections describe the performance of RR and PF scheduling algorithms in two different scenarios.

*A. **Scenario 1**: No fading without and with mobility*

In this scenario, a CBR connection is established between each pair of stationary UEs in a no fading environment. Simulation has been carried out with the data rate of 200Kbps for each CBR connection and performance metrics such as aggregate throughput, average end-to-end delay and average jitter of connections are recorded. Simulation studies are repeated by changing the data rate of each CBR connections insteps of 200Kbps up to 2Mbps and further insteps of 1Mbps up to 4Mbps.

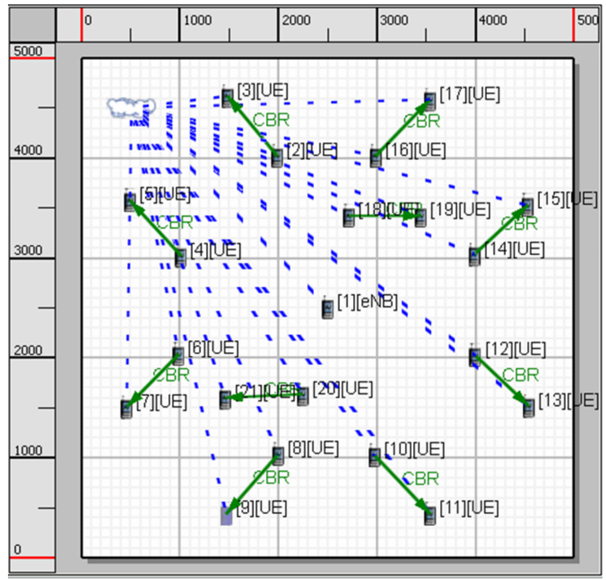


Figure 2. Snapshot of the Scenario designed for simulation study

In order to analyze the effect of mobility on performance metrics in no fading environment, simulation studies are repeated by enabling random mobility of 100Kmph to all the UEs. Fig. 3 shows the plot of aggregate throughput for different CBR data rates in no fading environment.

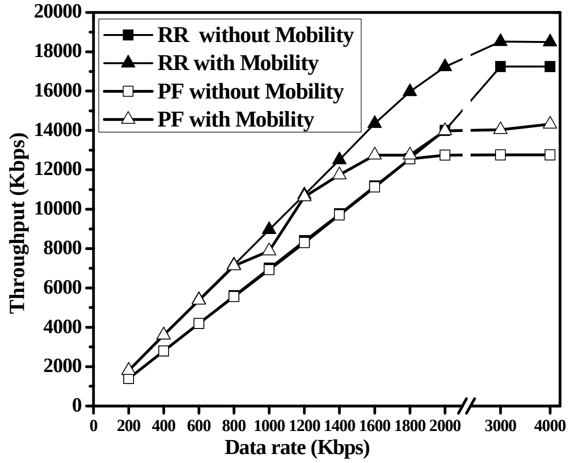


Figure 3. Aggregate throughput performance for different CBR data rates in no fading environment

It is observed from Fig. 3 that the throughput performance of both RR and PF scheduling algorithms is similar for lower data rates (up to 1.8Mbps) and RR performs better for higher data rates. The graph shows that the aggregate throughput for both scheduling algorithms saturates for higher data rates as PRBs required by individual users increases with data rate leading to scarcity of resource blocks [11][12]. Also, the overall throughput performance of RR is better than PF in no fading environment, since RR scheduling algorithm does not have an additional overhead of allocating resources dynamically depending on channel conditions which is present in PF scheduling algorithm [10].

It is also observed that both RR and PF scheduling algorithms perform better for the UEs moving at vehicular speed than stationary UEs. Since UEs at the cell edge move towards better Modulation and Coding Scheme (MCS) regions and thus improving the overall throughput performance [13].

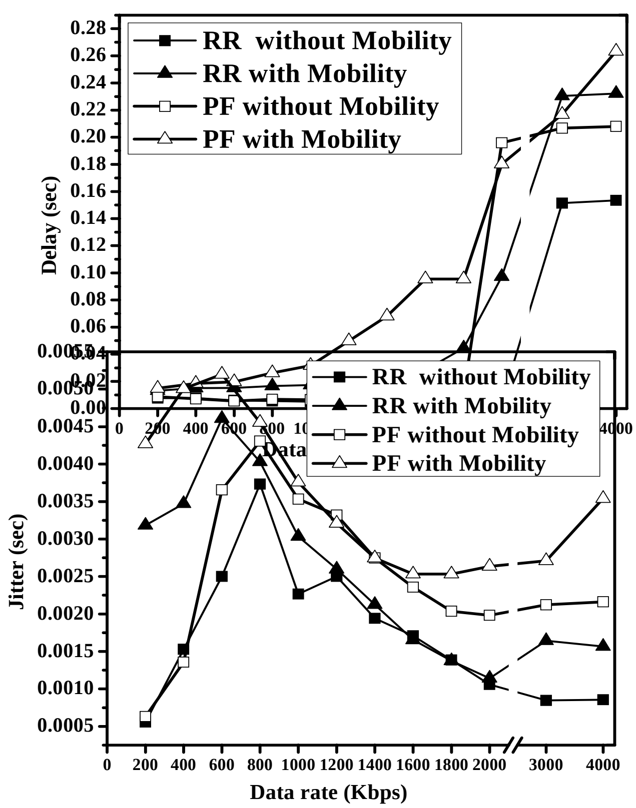


Figure 4. Average delay performance for different CBR data rates in no fading environment

Figure 5. Average jitter performance for different CBR data rates in no fading environment

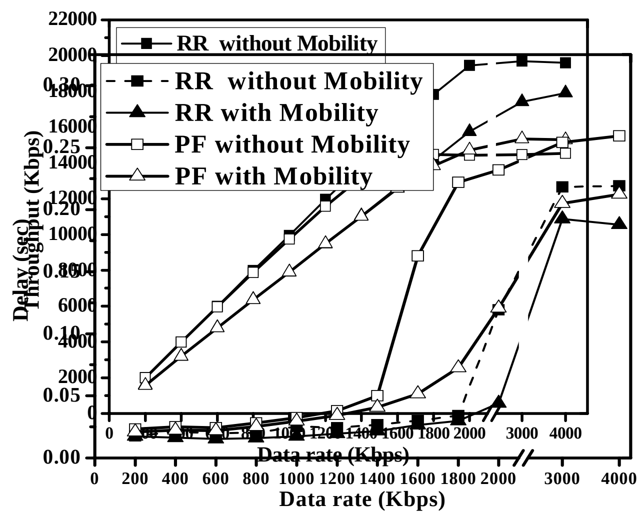
The average delay and jitter performance of RR and PF scheduling algorithms for different CBR data rates in no fading environment are shown in Fig. 4 & 5 respectively. The delay and jitter performance of RR scheduling algorithm is better than the PF, since resource allocation remains constant for CBR connections. At higher data rates, there is an increase in the number of PRBs required by individual user which leads to an additional delay [11].

B. ***Scenario 2***: *Rayleigh fading without and with mobility*

Retaining all the parameters of scenario 1, Rayleigh fading environment has been introduced in scenario 2 to study the effect of fading on performance of RR and PF scheduling algorithms. Simulation studies are repeated by considering same metrics as in scenario 1. Fig. 6 shows the plot of aggregate throughput for different CBR data rates in Rayleigh fading environment.

Figure 6. Aggregate throughput performance for different CBR data rates in Rayleigh fading environment

Fig. 6 depicts that the aggregate throughput performance of RR and PF scheduling algorithms in Rayleigh fading environment follows a similar trend as observed in no fading environment. It is observed (Fig. 3 & 6) that the throughput performance of RR scheduling algorithm in Rayleigh fading environment is marginally higher than in no fading environment. Further, RR scheduling algorithm outperforms



PF scheduling algorithm in no fading and Rayleigh fading environment.

Figure 7. Average delay performance for different CBR data rates in Rayleigh fading environment

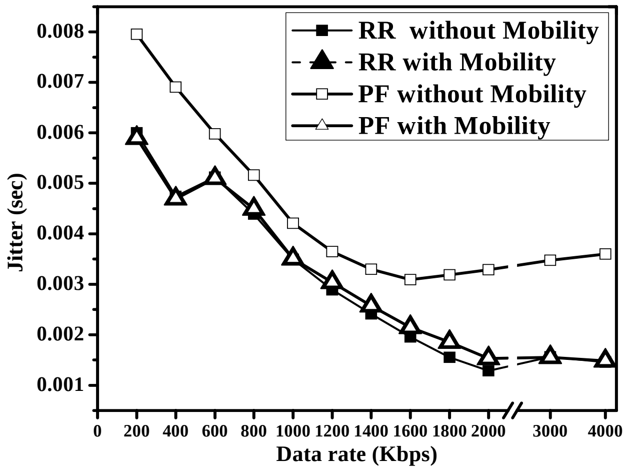


Figure 8. Average jitter performance for different CBR data rates in Rayleigh fading environment

The average delay and jitter performance of RR and PF scheduling algorithms for different CBR data rates in Rayleigh fading environment are shown in Fig. 7 & 8 respectively.

From the Fig. 4, 5, 7 & 8, it is observed that the delay and jitter performance of RR scheduling algorithm is marginally better in no fading environment than in Rayleigh fading environment. It is also observed that the delay and jitter performances of RR scheduling algorithm is better than that of PF scheduling algorithm in no fading and Rayleigh fading environment.

VI. CONCLUSION

In this paper, performance of RR and PF scheduling algorithms in LTE network is compared through simulation studies considering throughput, delay and jitter as performance metrics. The simulation results show that the performance of RR is better than PF for various CBR data rates for stationary as well as UEs at vehicular mobility, in no fading and fading environment.

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REFERENCES

[1] Luis Pérez, Luis Velasco, Juan Rodríguez, Pedro Capelastegui, Guillem Hernández-Sola, Lorena Calavia, Antonio Marqués, Borja Iribarne, Amador Pozo and Antoine De Poorter, “Network convergence and QoS for future multimedia services in the VISION project”, Computer Networks 56, 1183–1199, DOI:10.1016/j.comnet.2011.11.018, 2012.

[2] 3GPP TS 36.300, “E-UTRA and E-UTRAN Overall Description”, v8.4.0, (2008-03).

[3] Erik Dahlman, Stefan Parkvall and Johan Sköld, “4G LTE/LTE-Advanced for Mobile Broadband”, Copyright © 2011

[4] 3GPP TS 36.133, “Evolved Universal Terrestrial Radio Access (E-UTRA) Requirements for support of radio resource management”, v8.1.0, (2008-03).

[5] M. Corici, F. Gouveia and T. Magedanz, “A Network Controlled QoS Model over the 3GPP System Architecture Evolution,” Proceedings of the 2nd International Conference on Wireless Broadband and Ultra Wideband Communications, 2007

[6] Li Li and Subin Shen, “End-to-End QoS performance management across LTE networks” Network Operations and Management Symposium (APNOMS), 2011

[7] S. M. Chadchan and C. B. Akki, “3GPP LTE/SAE: An Overview”, International Journal of Computer and Electrical Engineering, Vol. 2, No. 5, October, 2010, Pp(s):1793-8163.

[8] Preethi Chandur, Karthik R.M and Krishna M. Sivalingam, “Performance Evaluation of Scheduling Algorithms for mobile WiMAX”, IEEE International Conference on Pervasive Computing and Communications Workshops , 2012**,** Pp(s): 764 – 769

[9] Xin Y uan and Zhenhai Duan ,“FRR: a Proportional and Worst-Case Fair Round Robin Scheduler”, Proceedings of IEEE INFOCOM, ISBN: 0-7803-8968-9, DOI : 10.1109/INFCOM.2005.1498314, vol. 2, Page(s): 831 - 842

[10] Claude Simon and Geert Leas “Round-Robin scheduling for time-varying channel with limited feedback”, IEEE 10th workshop on signal processing advances in wireless communication, 2009, ISBN-978-1-4-4244-3695-8, DOI: 10.1109/SPAWC.2009.5161781, Pp(s): 231-234

[11] M. Saad ElBamby and Khaled M. F. Elsayed, “A Transportation Problem based Resource Allocation Scheme for an LTE-Advanced System with Carrier Aggregation”, IFIP Wireless Days, 2012, Pp(s): 1 - 6, ISBN: 978-1-4673-4402-9, DOI: 10.1109/WD.2012.6402869

[12] Juan J. Sánchez, D. Morales-Jiménez, G. Gómez, J. T. Enbrambasaguas, “Physical Layer Performance of Long Term Evolution Cellular Technology”, 16th IST Mobile and Wireless Communications Summit, 2007, Pp(s):1-5, ISBN: 963-8111-66-6, DOI: 10.1109/ISTMWC.2007.4299090

[13] F. Capozzi, G. Piro, L. Grieco, G. Boggia and P. Camarda, “Downlink Packet Scheduling in LTE Cellular Networks: Key Design Issues and a Survey”, IEEE Communications Surveys & Tutorials, Pp(s): 1-23, DOI: 10.1109/SURV.2012.060912.00100

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